Late outcomes of mitral valve repair for floppy valves: Implications for asymptomatic patients

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Objectives: We sought to evaluate the long-term results of mitral valve repair in patients with mitral regurgitation caused by floppy mitral valves and compare the outcomes of asymptomatic patients with those of symptomatic patients.

Methods: A retrospective review of 488 consecutive patients who had mitral valve repair for floppy mitral valve disclosed 199 patients who were asymptomatic or had minimal symptoms and 289 patients who were symptomatic at the time of the operation. Asymptomatic patients were younger, had better ventricular function, had a lower incidence of coronary artery disease, and had higher rates of atrial fibrillation than symptomatic patients.

Results: Survival at 15 years was 61% for all patients. Survival was 76% for asymptomatic patients, which was identical to that for the general population matched for age and sex, whereas the survival of symptomatic patients was 53% and significantly lower than that of the general population. Cox regression analyses validated by means of bootstrap methodology identified the following predictors of late death: age by increments of 5 years (risk ratio = 1.2), New York Heart Association functional classes 3 and 4 (risk ratio = 3.0), left ventricular ejection fraction of less than 40% (risk ratio = 2.7), preoperative stroke or transient ischemic attack (risk ratio = 3.1), previous cardiac operation (risk ratio = 4.6), and severe chronic obstructive pulmonary disease (risk ratio = 3.1). Freedom from reoperation at 15 years was 91%, and it was similar for asymptomatic and symptomatic patients. Freedom from mitral regurgitation of greater than 2+ at 15 years was 85% for all patients, 96% for asymptomatic patients, and 76% for symptomatic patients.

Conclusions: This study supports the recommendation of surgical intervention in asymptomatic patients with mitral regurgitation caused by a floppy mitral valve if mitral valve repair is feasible and associated with low operative mortality and morbidity.

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Floppy mitral valves are very common. In the Framingham Heart Study they were found in 2.5% of men and 7.6% of women by means of M-mode echocardiography.¹ In a large autopsy study by Davies and associates,² the frequency was 3.9% in men and 5.2% in women. Mitral regurgitation (MR) is an uncommon complication of a floppy mitral valve,^{1,2} but because this entity is very prevalent, MR as a result of mitral valve prolapse is the most common cause of MR in North America.³

TABLE 1. Clinical profile of patients with and without symptoms

	All patients	Asymptomatic	Symptomatic	<i>P</i> value
No. of patients	488	199	289	
Age, mean $\pm$ SD (y)	58 $\pm$ 13	54 $\pm$ 14	61 $\pm$ 12	.01
Male sex	347 (71)	150 (75)	197 (68)	.08
Medical history				
Congestive heart failure	318 (65)	61 (31)	257 (89)	.0001
Stroke/TIA	31 (6)	9 (4)	22 (8)	.17
Hypertension	125 (26)	37 (19)	88 (30)	.003
Renal failure (dialysis)	4	1	3	.51
COPD (FEV ₁ <1.0)	15 (3)	0	15 (5)	.001
Diabetes mellitus	19 (4)	4 (2)	15 (5)	.07
Endocarditis				
Healed	40 (9)	23 (11)	24 (8)	.41
Active	3	1	3	
Marfan syndrome	7	6	1	.17
Previous heart operations	10	5	5	.54
Aortic valve replacement	2	0	2	
Mitral valve repair	4	3	1	
Atrial septal defect	2	1	1	
Coronary artery bypass	2	1	1	
Electrocardiogram				
Sinus rhythm	344 (70)	175 (88)	169 (59)	
Atrial fibrillation	140 (29)	23 (11)	117 (40)	.0001
Heart block/pacemaker	4	1	3	
Associated cardiac diseases				
Aortic root/ascending aneurysm	13 (3)	8 (4)	5 (2)	.12
Aortic valve disease	38 (8)	19 (10)	19 (7)	.22
Tricuspid valve disease	15 (3)	2 (1)	13 (4)	.028
Coronary artery disease	81 (17)	22 (11)	59 (20)	.006
HOCM	5	0	5 (2)	.06
Left ventricular ejection fraction				
$\geq$ 60%	230 (47)	125 (63)	105 (36)	
41%-59%	228 (47)	70 (35)	158 (55)	
21%-40%	28 (6)	4 (2)	24 (8)	
$\leq$ 20%	2	0	2	.0001

Percentages are shown in parentheses. *P* values are for the differences between asymptomatic and symptomatic groups. *COPD*, Chronic obstructive pulmonary disease; *FEV₁*, forced expiratory volume in 1 second; *HOCM*, hypertrophic obstructive cardiomyopathy.

The onset of MR in patients with floppy mitral valves is often insidious, and symptoms might not occur until the left ventricle fails. In the past, the indication for surgical intervention was based on the burden of symptoms versus the risk and uncertainties of mitral valve replacement. At present, surgical intervention is recommended in asymptomatic patients with severe MR to prevent left ventricular dysfunction as long as the mitral valve can be repaired with low operative mortality.^{4,5}

This study is an analysis of the clinical and echocardiographic outcomes of mitral valve repair for MR caused by floppy mitral valves in patients with and without symptoms.

Patients and Methods

From 1981 to 1998, 612 patients with MR caused by floppy mitral valves underwent mitral valve surgery performed by one surgeon. Mitral valve repair was performed in 488 (80%) patients, and mitral valve replacement was performed in 124 (20%) patients. The ratio between mitral valve repair and mitral valve replacement

for mitral valve prolapse increased from 25% in 1981 to 90% to 95% after 1990.

Patients were divided into 2 groups: asymptomatic and minimally symptomatic patients (New York Heart Association [NYHA] functional classes 1 and 2) and symptomatic patients (NYHA functional classes 3 and 4). In the first group 55 patients had no symptoms of heart disease, and 144 had minimal symptoms, and in the second group 212 were in functional class 3, and 77 were in functional class 4. Table 1 shows the clinical profile of all patients, as well as the clinical profiles of the 2 groups. Most asymptomatic patients (NYHA functional class 1) were operated on because of impaired left ventricular systolic function or aortic root aneurysm.

Most operations were performed electively, but 69 patients required urgent surgical intervention because of intractable congestive heart failure, active infective endocarditis, or both.

Operative Procedures

The techniques of mitral valve repair used in this series were basically those described by Carpentier,⁶ but certain modifications

TABLE 2. Operative data

	All patients	Asymptomatic	Symptomatic
Mitral valve prolapse			
Posterior leaflet	238 (49)	103 (52)	135 (47)
Anterior leaflet	73 (15)	30 (15)	43 (15)
Bileaflet	177 (36)	66 (33)	111 (38)
Mitral valve repair			
Partial resection of posterior leaflet	415 (85)	169 (85)	246 (85)
Chordal replacement with PTFE*	289 (69)	115 (58)	174 (60)
Chordal shortening	63 (14)	19 (9)	44 (15)
Chordal transfer	12 (3)	0	12 (4)
Annuloplasty	439 (90)	173 (87)	266 (92)
Mitral annulus reconstruction	11 (2)	2 (1)	9 (3)
Aortic valve repair	21 (5)	11 (5)	7 (2)
Aortic valve replacement	17 (4)	5 (2)	12 (4)
Replacement of ascending aorta/sinuses	13 (3)	8 (4)	5 (2)
Tricuspid valve repair	15 (3)	2 (1)	13 (4)
Coronary artery bypass	81 (17)	22 (11)	59 (20)
Maze procedure	23 (5)	4 (2)	19 (7)
Septal myectomy	5 (1)	2 (1)	3 (1)

Percentages are shown in parentheses.

*Gore-Tex, registered trademark of W.L. Gore & Associates, Inc, Flagstaff, Ariz.

were introduced over the years. The first was the use of expanded polytetrafluoroethylene (ePTFE) sutures to reinforce or replace chordae tendineae in 1985.⁷ Another change was the method of resection of the central scallop of the posterior leaflet. Quadrangular or rectangular resection of the posterior leaflet with plication of the mitral annulus was replaced by a more triangular resection with detachment of a portion of the posterior leaflet from the mitral annulus and sliding plasty to prevent kinking or damage of a dominant circumflex artery and to reduce the risk of systolic anterior motion of the anterior leaflet.^{8,9} Finally, the annuloplasty ring was first changed from a rigid to a flexible ring and then to a posterior band. A few patients with horseshoe calcification of the mitral annulus had mitral valve repair with excision of the calcium bar and creation of a new mitral annulus with autologous pericardium.¹⁰

Since 1994, all patients with chronic atrial fibrillation had the maze procedure at the time of mitral valve repair.¹¹

Table 2 lists what leaflet was prolapsing and what operations were performed.

Patients were anticoagulated with warfarin sodium during the first 3 postoperative months if they were in sinus rhythm and permanently if they were in atrial fibrillation.

Follow-up

Patients were followed by the referring cardiologist and contacted by our research personnel every other year through a comprehensive questionnaire. They were interviewed by telephone when the cardiologist or the patient reported an adverse event. Echocardiograms were obtained yearly in most patients. Follow-up was ended in December 2001. The mean follow-up time was 7.1 years (range, 3-19 years) for the entire group; it was 6.8 ± 3.5 years for asymptomatic and 7.3 ± 3.8 for symptomatic patients. The follow-up was complete.

Statistical Analysis

All data analyses were performed with SAS 8.1 software (SAS Institute, Cary, NC). Descriptive statistics are reported as the mean $\pm$ SD for continuous variables and as frequencies and percentages for categorical variables unless otherwise noted. Comparisons between the asymptomatic and symptomatic groups were made with unpaired *t* tests for continuous variables and χ^2 or Fisher exact tests for categorical variables. Estimates for long-term survival or freedom from morbid events were made by using the Kaplan-Meier method. The difference between survival curves was evaluated by using the log-rank statistic. Age- and sex-matched Ontario survival estimates were obtained from the Life Table Template V1.2, a downloadable Excel spreadsheet developed by the Central East Health Information Partnership and available at its Web site (<http://www.cehip.org>).

All preoperative candidate variables were entered into Cox regression analyses to determine the independent multivariable predictors of late outcomes. The appropriateness of variable transformations was determined by means of univariate analysis. Variables with a univariate *P* value of less than .25 or those with known biologic significance but failing to meet this critical α level were submitted to the multivariable model. Criterion for retention of variables in the model was set at a *P* value of .05. The following variables were submitted to all multivariable models: age by 5-year increments, sex, NYHA functional class, left ventricular grade, preoperative atrial fibrillation, preoperative stroke or transient ischemic attack (TIA), previous heart surgery, coronary artery disease, congestive heart failure, urgent-emergency surgery, ascending aortic aneurysm, concomitant aortic valve surgery, hypertension, diabetes, and chronic obstructive lung disease. The adjusted risk ratios for the independent predictors and their 95% confidence intervals are presented in the tables.

The Cox models were validated by using bootstrap methodology. Two hundred random data sets of 400 patients each were drawn from the original data set. The Cox model was rerun in each data set. The frequency with which the variable remained in the models was considered an indicator of the importance of the variable as an independent predictor of outcome. A variable was rejected if it did not occur in at least 50% of the models. In addition, the risk ratios were averaged across the 200 models to indicate the validity of the magnitude of the association.

Results

The 2 groups of patients in this study had different clinical profiles, as seen in Table 1. Particularly important is the fact that symptomatic patients were older, had higher rates of chronic atrial fibrillation, had worse left ventricular function, and had a higher incidence of coronary artery disease than asymptomatic patients.

Patient Survival

There were 5 operative deaths and 73 late deaths, as listed in Table 3. Asymptomatic patients had significantly fewer cardiac and valve-related deaths than symptomatic patients ($P = .001$). A stepwise logistic regression analysis identified age by increments of 5 years, NYHA functional classes 3 and 4, impaired left ventricular function, preoperative stroke or TIA, previous cardiac surgery, and chronic obstructive pulmonary disease as independent predictors of late mortality, as shown in Table 4. Bootstrap validation of these variables is also shown in Table 4.

Table 5 shows the Kaplan-Meier estimates of freedom from valve-related, cardiac-related, and other causes of death in the 2 groups of patients. Age by increments of 5 years, atrial fibrillation, and hypertension were independent predictors of valve-related death. Table 6 shows the risk ratio for these variables with bootstrap validation.

Figure 1 shows survival of all patients in comparison with that of the general population matched for age and sex. Figure 2 shows the survival of the 2 groups of patients and the general population of Ontario matched for age and sex. Asymptomatic patients had the same survival as the general population of Ontario, whereas symptomatic patients had significantly lower survival.

Valve-Related Complications

Thromboembolic complications occurred in 50 patients: 20 had TIA, and 30 had stroke.

Seven patients had infective endocarditis: 3 underwent mitral valve replacement, 1 underwent reoperation, and 3 were treated with antibiotics alone. All patients survived.

A total of 104 patients were taking coumadin at the time of the last follow-up contact because of atrial fibrillation, a postoperative thromboembolic event, or both. Major bleeding related to anticoagulation occurred in 9 patients, and it was fatal in 2 patients.

TABLE 3. Causes of death

	Asymptomatic	Symptomatic
Operative deaths		
Dehiscence of aortic homograft		1
Myocardial infarction		2
Hemorrhagic stroke	1	
Intestinal volvulus with peritonitis		1
Late deaths		
Valve related		
Anticoagulation-related bleeding		5
CHF caused by MR		1
Stroke	1	6
Cardiac related		
CHF		8
Sudden	1	5
Myocardial infarction	1	4
Aortic valve replacement	0	1
Nonvalvular, noncardiac	7	33

CHF, Congestive heart failure.

Twenty-three patients who had the maze procedure were alive at the last follow-up contact; 19 were in sinus rhythm, 2 had atrioventricular paced beats, and 1 was in atrial fibrillation. None of these patients had a postoperative thromboembolic event.

Mitral valve reoperation was performed in 22 patients: 3 for dehiscence of the annuloplasty ring, 3 for hemolysis, 2 for mitral stenosis caused by pannus, 4 for endocarditis, 1 for a left ventricular coronary sinus fistula, and 9 because of recurrent MR caused by chordal elongation or rupture. All patients survived reoperation. The mitral valve was rerepaired in 7 and replaced in 15 patients. Figure 3 shows the freedom from reoperation in asymptomatic and symptomatic patients.

Eleven patients had severe MR: 10 were successfully reoperated on, and 1 was deemed inoperable and died in congestive heart failure. Sixty-six patients had moderate MR, as determined by means of echocardiography, during the follow-up period. Figure 4 shows the freedom of MR of greater than 2+ in asymptomatic and symptomatic patients.

Table 7 shows the Kaplan-Meier estimates of freedom from various morbid events at 5, 10, and 15 years postoperatively.

There were no predictors of reoperation, thromboembolic events, or recurrent MR by means of a stepwise logistic regression analysis.

Although the rates of valve-related complications were lower in asymptomatic than in symptomatic patients, the differences between the 2 groups did not reach statistical significance.

Late Functional Class

At the last follow-up, 137 (76%) patients in the asymptomatic group were in NYHA class 1, 31 (17%) were in class 2,

TABLE 4. Predictors of late mortality by means of Cox regression analysis with bootstrap validation

	RR (95% CI)	P value	Bootstrap validation	
			%	Average d RR
Age/5 y	1.24 (1.1-1.4)	.002	96	1.23
NYHA class 3 and 4	3.00 (1.3-6.8)	.008	90	3.29
Ejection fraction <40%	2.68 (1.4-5.3)	.004	89	3.16
Preoperative stroke/ TIA	3.15 (1.6-6.1)	.001	94	3.25
Redo operation	4.61 (1.4-15)	.012	63	5.16
COPD	3.13 (1.4-7.0)	.005	76	3.56

Bootstrap validation is defined as 200 randomly selected sets of 400 patients each. Percentages are defined as frequencies with which the variable was an independent predictor of the outcome. *RR*, Risk ratio; *CI*, confidence interval; *COPD*, chronic obstructive pulmonary disease.

Figure 1. Survival after mitral valve repair in comparison with that in the general population matched for age and sex, as depicted by the dashed line.

and 12 (7%) were in class 3. In the symptomatic group, 129 (60%) were in class 1, 39 (28%) were in class 2, 24 (11%) were in class 3, and 2 were in class 4. One patient was scheduled for mitral valve reoperation for late mitral stenosis.

Discussion

Most clinical investigators believe that mitral valve repair results in a higher long-term survival than mitral valve replacement in patients with mitral valve prolapse.¹² Our study indicates that late survival after mitral valve repair depends on various factors, and in fact, the overall survival is lower than that of the general population matched for sex and age. Asymptomatic patients with severe MR caused by floppy valves had identical long-term survival as the general population matched for age and sex, whereas symptomatic patients had significantly lower survival when compared with the general population. Thus surgical intervention is indicated in asymptomatic patients with severe MR if preoperative multiplane echocardiography indicates that the mitral valve is repairable and operations can be performed with low operative mortality and morbidity. Preoperative

TABLE 5. Kaplan-Meier estimates of freedom from valve-related deaths, cardiac deaths, and other deaths

Freedom from:	5 y	10 y	15 y	P value*
Valve-related death				
NYHA 1-2	100	100	92 ± 2	.008
NYHA 3-4	97 ± 1	94 ± 3	86 ± 5	
Cardiac death				
NYHA 1-2	99 ± 1	99 ± 1	89 ± 9	.005
NYHA 3-4	97 ± 1	92 ± 2	88 ± 4	
Other death				
NYHA 1-2	98 ± 1	93 ± 3	93 ± 3	.016
NYHA 3-4	97 ± 1	85 ± 3	72 ± 7	

*Kaplan-Meier P value.

TABLE 6. Predictors of valve-related death by means of Cox regression analysis with bootstrap validation

	RR (95% CI)	P value	Bootstrap validation	
			%	Average d RR
Age/5 y	1.72 (1.2-2.5)	.007	86	1.83
Preoperative arial fibrillation/flutter	4.41 (1.2-16)	.026	57	7.38
Hypertension	3.42 (1.1-10)	.032	51	6.95

RR, Risk ratio; *CI*, confidence interval.

echocardiography, particularly transesophageal echocardiography, is currently the best diagnostic tool to determine the ability for mitral valve repair.¹³ We believe that mitral valve repair is feasible in all patients with single or bileaflet prolapse as long as the leaflets are not excessively thickened and the mitral annulus, the chordae tendineae, and the papillary muscles are not calcified.

In addition to the severity of symptoms, left ventricular ejection fraction of less than 40%, preoperative stroke or TIA, previous cardiac surgery, and severe chronic obstructive pulmonary disease were also found to be predictors of late mortality in our study. We had expected to find that

Figure 2. Survival after mitral valve repair in asymptomatic and symptomatic patients in comparison with that in the general population matched for age and sex, as depicted by the thinner lines.

Figure 3. Freedom from reoperation in asymptomatic and symptomatic patients.

coronary artery disease was also a predictor of late death, but this was not the case, as examined by means of Cox regression analysis validated by using bootstrap methodology. In previous studies on longitudinal outcomes of aortic and mitral valve surgery from our institution, coronary artery disease emerged as an important predictor of late mortality.^{14,15} The presence of aortic or tricuspid valve disease was not predictive of poor outcome either, although only a small proportion of our patients had these associated valve problems. It is possible that other noncardiac diseases in addition to severe chronic obstructive pulmonary disease might affect the long-term outcome if a larger sample size had been analyzed.

Patients who have successful mitral valve repair for floppy mitral valve disease continue to be exposed to risks of cardiac and valve-related complications. Sudden death and congestive heart failure are common among patients with floppy mitral valves; correction of the MR decreases the risk of these complications, but it does not abolish them

Figure 4. Freedom from MR of greater than 2+.

TABLE 7. Kaplan-Meier estimates of freedom from morbid events in all patients

Freedom from:	5 y	10 y	15 y
Valve-related death	98 ± 1	95 ± 1	89 ± 4
Cardiac death	98 ± 1	95 ± 1	89 ± 4
Other death	97 ± 1	88 ± 2	79 ± 5
Reoperation	96 ± 1	93 ± 2	91 ± 4
Thromboembolism	93 ± 1	87 ± 2	76 ± 6
Endocarditis	99 ± 1	98 ± 1	98 ± 1
Major bleeding	99 ± 1	98 ± 1	93 ± 4
Valve-related mortality-morbidity	89 ± 1	78 ± 2	61 ± 6
Recurrent MR (>2+)	99 ± 1	94 ± 2	85 ± 7

completely.^{16,17} Grigioni and associates¹⁶ found that sudden death was relatively common in patients with MR caused by mitral valve prolapse. NYHA functional class, left ventricular ejection fraction, and atrial fibrillation were found to be independent predictors of sudden death by those investigators.¹⁶ Surgical correction of the MR reduced the risk, but it did not eliminate it. In our series of mitral valve repair, 6 of 20 cardiac deaths were sudden deaths, and one of them occurred in the asymptomatic group.

Congestive heart failure after surgical correction of MR is associated with poor long-term prognosis.¹⁷ The reason for heart failure is often poor postoperative left ventricular function, and it reinforces the notion that mitral valve surgery should be performed before left ventricular systolic function deteriorates.^{5,17,18} In our series of mitral valve repair, there were 8 late deaths caused by congestive heart failure, and 6 occurred among patients who had decreased left ventricular ejection fractions preoperatively. All of them were in the symptomatic group.

Stroke and TIA are relatively common in patients with mitral valve prolapse, but these patients often have other causes for cerebral ischemia.^{19,20} We could not establish the reason why preoperative stroke or TIA was predictive of late mortality in our series. Only 31 patients had experi-

enced this complication preoperatively, and the high mortality among them might have been by chance alone. Patients with floppy mitral valves have a constant risk of stroke or TIA after mitral valve repair, as described in this study and in others.^{12,21}

Atrial fibrillation increases the risk of thromboembolism, as well as the risk of hemorrhage, because these patients are taking oral anticoagulants. Atrial fibrillation was identified as an independent predictor of valve-related death in this series, but it had no effect on overall survival. Since 1994, we have combined the Cox-maze procedure with mitral valve repair in patients in chronic atrial fibrillation.¹¹ We believe that it reduces the risk of thromboembolism and the need for oral anticoagulation.¹¹ Our experience is still too small to determine its effect on valve-related deaths.

The risk of infective endocarditis in patients with mitral valve prolapse and MR is probably reduced but not abolished after mitral valve repair. Seven patients in our series had endocarditis, and 4 required mitral valve replacement.

Although floppy mitral valve disease is a degenerative disorder that is likely progressive, the long-term durability of mitral valve repair has been excellent.^{12,21,22} The freedom from reoperation at 15 years was 91% in our series. Other investigators reported similar results.²² It has been pointed out that the durability of repair of posterior leaflet prolapse is better than that of anterior leaflet prolapse,^{12,21,22} but this has probably changed since the introduction of newer operative techniques to repair prolapse of the anterior leaflet.²³ Indeed, we could not identify any predictor of recurrent MR or reoperation in our present series, and the results with isolated prolapse of the posterior leaflet were similar to those of anterior or bileaflet prolapse. We believe that the use of ePTFE sutures to replace elongated or ruptured chordae tendineae has made a major difference in increasing the probability of mitral valve repair in patients with anterior leaflet and bileaflet prolapse, as well as increasing the durability of the repair.^{7,23} Several investigators have shown that chordal transfer is better than chordal shortening²⁴ and that chordal replacement with ePTFE is better than chordal shortening.²⁵ Since we introduced ePTFE sutures to replace chordae tendineae in our practice, we have slowly abandoned both chordal shortening and chordal transfer in favor of chordal replacement. Although we have had recurrent MR in patients who had chordal replacement with ePTFE sutures, the cause of recurrent MR was unrelated to the synthetic chordae.

Although most surgeons agree that an annuloplasty ring or posterior band is needed in patients with floppy mitral valves, its value has been questioned repeatedly.^{26,27} We believe that annular reduction is an important part of mitral valve repair for floppy valve disease because the fibrous annulus is often involved in the degenerative process, is always dilated, and is sometimes posteriorly displaced

along its attachment with the left ventricle.²⁸ These abnormalities must be corrected to obtain a durable repair.

This is a retrospective study of a clinical experience of a single surgeon, and the results might not be generalizable. The prevalence of associated cardiac and noncardiac diseases was relatively small in this series, and statistical values of certain variables might have been altered by chance alone.

In conclusion, surgical intervention should be considered in asymptomatic patients with severe MR caused by floppy valves if valve repair is feasible, and it can be done with low operative mortality and morbidity because the late survival is identical to that of the general population. The durability of mitral valve repair for floppy valves is excellent, but valve- and cardiac-related complications in these patients are not entirely abolished with surgical intervention.

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Discussion

Dr Michael A. Acker (Philadelphia, Pa). I congratulate Dr David for this impressive series. This article represents the results of 17 years of experience repairing myxomatous mitral valve disease by a master surgeon. He has found, as Carpentier, Cosgrove, and others have, that the vast majority of even the most complex valve disorders can be repaired, and the repair is extremely durable, with an average reoperation rate of approximately 0.7% per year out to 15 years.

The results indicate that patients who are asymptomatic at the time of surgery have a lower operative mortality, fewer late cardiac deaths, and a normal life expectancy when compared with matched control subjects, which is in marked contrast to patients with symptoms at the time of surgical intervention. It is important, however, to note that symptoms per se were not predictive of late mortality. Rather the independent predictors were severe symptoms, such as class III or class IV heart failure, decreased left ventricular function with an ejection fraction of less than 40%, and increased age.

Dr David justifiably concludes that in his hands even the patient who is completely asymptomatic (ie, class I or 0) and who is

judged to have a repairable valve should undergo mitral valve repair. American College of Cardiology and American Heart Association guidelines already strongly endorse a class I indication for mitral valve repair in patients with mild symptoms and a class II indication, or patients who are totally asymptomatic if the ejection fraction is less than 60% and end-systolic diameter is greater than 45 mm. The recommendations for surgical intervention for the completely asymptomatic patient with severe MR who has normal left ventricular function and size, an ejection fraction of greater than 60%, and an end-diastolic dimension less than 45 mm is more equivocal, and they have it presently as a class IIb recommendation.

I have several questions. Because it is impossible to predict how long the truly asymptomatic patient with normal left ventricular function and size and severe MR will remain in this state and because there will always be a small but present operative mortality, such as there was in your study, would it not be better to have a strategy to follow echocardiographically these types of asymptomatic patients with normal left ventricular function and wait for the development of either very mild symptoms, a slight decrease in systolic function (eg, <60%), or an increase in left ventricular end-systolic dimensions (eg, >45 mm)?

How often after complex bileaflet repair was there mild-to-moderate residual MR (ie, 1 to 2+)? Did 1 to 2+ residual MR predict a later need for reoperation or the development of more severe MR? Do you presently accept 1 to 2+ MR after a complex bileaflet mitral valve repair?

As a follow-up of your earlier discussion of the first article, presently in an elderly patient greater than 65 years old with complex bileaflet disease and the need for extensive bileaflet procedures, do you think that patient would be equally served by mitral valve replacement with a bioprosthetic valve if the subchordal apparatus is to be completely retained?

Finally, obviously the key decision before recommending surgical intervention for the asymptomatic patient with normal left ventricular function is the likelihood of repair. With that in mind, can you comment on what the specific echocardiographic characteristics and diseases are that make you decide a valve is not repairable? Are these the same echocardiographic characteristics and diseases you would recommend a surgeon without your extensive experience and skill to shy away from or to monitor the patient further? How often did you attempt repair but fail and need to replace the valve? Finally, do you believe that your general recommendation for valve repair in asymptomatic patients with normal left ventricular function is generalizable to most cardiac surgeons and environments?

Dr David. Thank you, Dr Acker. When we first looked at these data, the first question that came to our minds was why we had operated on 55 patients without symptoms back in the 1980s. The answer was that most of them had impairment of left ventricular function, an enlarged left atrium, or an aortic root aneurysm. Our approach has changed, however, since we reviewed our experience. In the past 2 or 3 years, we have been offering surgical intervention to patients without symptoms and normal cardiac dimensions and systolic and diastolic function, which takes me to your fourth question, if I might answer it now.

In patients with severe MR and no symptoms, we obtain a transesophageal echocardiogram to take a close look at the mor-

phology and mechanism of mitral valve prolapse. If it is due to a single leaflet prolapse, we tell patients that the likelihood of repair is near 100%. It does not matter whether it is the anterior or the posterior leaflet. Since the introduction of polytetrafluoroethylene sutures to replace chordae tendineae, there is no leaflet prolapse that cannot be repaired. We have a 16-year experience with chordal replacement in several hundred patients, and we have never reoperated because of failure of the polytetrafluoroethylene chordae. For bileaflet prolapse with normal leaflets of normal thickness, we also offer surgical intervention. If the mitral annulus is larger than 60 mm, if the leaflets are more than 3 to 4 mm in thickness with prolapse of multiple segments, we do not offer surgical intervention and wait until there is a hemodynamic indication, such as impairment of systolic function or symptoms.

We do not accept more than 1+ MR after mitral valve repair, even when a complex repair is done, such as in patients with advanced myxomatous disease or a heavily calcified mitral annulus. The area of the regurgitant jet has to be less than 2 or 3 cm². Perhaps even more important than the amount of MR is the morphologic state of the mitral valve after repair. If the coaptation of the leaflets is not inside the ventricle, I believe the patient should go back on cardiopulmonary bypass and the valve should be rerepaired because this is probably the best predictor of late failure.

Finally, the elderly or the patient who needs a complex repair and has extensive coronary artery disease might be better served by mitral valve replacement with preservation of the chordae tendineae. Having said that, I would repair the mitral valve of an 85-year-old patient with triple-vessel disease if the mitral disease is simple, such as prolapse of a single segment.

Are our results generalizable to all surgeons? Probably not. I had my first lessons on mitral valve repair back in 1979 with Dr Alain Carpentier. My very first repair failed, and I was very disappointed because after watching Dr Carpentier operate, I thought that there was nothing to mitral valve repair. It took me another 6 months to be brave enough to repair the second case. This one worked very well, and I did a third with equal success. The fourth failed, but the next 10 did well, and I think by that time I had passed the initial learning curve. Like anything else in life, the more you practice, the better you get at it. Beginners should start to repair simple valve disorders, such as prolapse of P2 or rupture of a single chorda to the anterior leaflet, and then progressively take on more complex cases.

Dr Alain F. Carpentier (*Paris, France*). I rise to congratulate Tirone for this excellent presentation and for raising the question of asymptomatic patients. First, I have a comment. It is hard for me to understand when you are talking about a floppy mitral valve. Do you mean only the Barlow syndrome, or do you incorporate all types of degenerative valvular disease, including fibroelastic deficiency?

Dr David. The entire spectrum of mitral valve prolapse caused by degenerative disease is included, Professor Carpentier. In other words, I include fibroelastic deficiency, Barlow syndrome, myxomatous degeneration, floppy mitral valve, those who have a segment that prolapsed because of rupture of the chordae tendineae, elongation, or degenerative changes. Ischemic and rheumatic causes are excluded.

Dr Carpentier. It would be nice to have a common agreement separating the diseases from the dysfunction and talking about prolapse when there is a dysfunction.

Dr David. Professor Carpentier, when I finished the course with you, I returned home and told my cardiac pathologist that you distinguished leaflet prolapse caused by fibroelastic deficiency from myxomatous degeneration. His reply was that they were the same disease. From that time on, I have referred to them as floppy mitral valves.

Dr Carpentier. I would be delighted to have the address of your pathologist and to challenge him on pathology. He is making a confusion between a primary disease and a secondary relation caused by the dysfunction.

Dr David. Professor Carpentier, let me add that I have used the classification you taught me back in 1980, and less than 5% of my patients have what you refer to as fibroelastic deficiency.

Dr Carpentier. Let us concentrate on the most important aspect of your article. I really congratulate you on raising the question of asymptomatic patients. I have a hard time convincing our patients, even with the large experience we have, to undergo surgical intervention if they are totally asymptomatic with normal left ventricular function and normal left ventricular dimension because we still have, let us say, even less than 0.4% operative mortality. Everything can happen during surgical intervention, and therefore it would be extremely difficult to justify and to advise young surgeons to operate on totally asymptomatic patients, whereas we can have some more sound data to tell them, "Okay, we have to operate on you because you have an involuted process with small, progressive enlargement of the left ventricle." Wouldn't you agree with that policy?

Dr David. Yes, I would agree with your policy.

Dr Carpentier. Do not push too much, too far.

Dr David. However, there are a couple of studies on the natural history of patients with mitral valve prolapse and no symptoms. They have a risk of approximately 0.5% per year for sudden death syndrome, 0.2% per year for endocarditis. If you add that over 10 years most if not all have symptoms, ventricular dysfunction, or both, and then it makes sense to operate earlier.

Dr Carpentier. Your point is very well taken. However, this group of patients having a sudden death belong to a very specific pathology group that we have to discuss with your pathologist.

Anyway, my third and very brief question is the following. You had a 15% incidence of residual moderate-to-severe residual insufficiency after 15 years, which is good. However, as usual, I am interested to know the causes of these recurrent or residual insufficiencies within this 15-year time frame.

Dr David. This was not residual but rather recurrent MR. We started with a 98% freedom from moderate or severe MR by the end of the first postoperative year. To be quite honest, I have 2 previous studies on longitudinal outcomes of mitral valve repair, and in both of them I made inferences that the recurrence in the first decade is largely the result of technical errors. Now I have to add that even if you do a perfect job in the operating room, the degenerative disease is progressive, and by 15 years, most of my patients who had recurrent MR did so because of prolapse of segments that were normal before.

Mr Magdi H. Yacoub (*London, United Kingdom*). I enjoyed your presentation, Dr David. I have 2 very minor questions. First,

what is your definition of asymptomatic? If a patient had a history of heart failure, pulmonary edema, or both, or suddenly had worsening in mitral valve disease, does that patient remain asymptomatic if he was asymptomatic at the time of assessment? In the same vein, would you consider using exercise capacity with gas exchange, for example, to define your asymptomatic group? Second, have you compared the severity of MR in your 2 groups by some sort of an objective method, such as regurgitant fraction or effective regurgitant orifice or one of these indices?

Dr David. I have a database on all patients operated on since I started practicing. One of the entries is the NYHA functional classification. In this study we identified as “asymptomatic” and “minimally symptomatic” patients who were in functional classes I and II, respectively. We did not exercise our asymptomatic patients. I do not know the value of exercise tests in patients with MR. We do that in asymptomatic patients with aortic insufficiency before we recommend surgical intervention.

We quantitate MR by means of echocardiography. We call it severe when there is a large jet and reversal of pulmonary venous flow. Both groups of patients in this series had severe MR.

Dr Kevin D. Accola (*Orlando, Fla*). Thank you, Dr David, for a very informative series.

As one of the younger surgeons to whom Professor Carpentier alluded, from a technical standpoint, I noticed that in 8% to 10% of your patients, you did not use an annuloplasty ring. Could you describe your decision process in those patients? Did they subse-

quently reflect in any of your results requiring reoperation where any of your patients came back with significant insufficiency?

Dr David. Recurrent MR was unrelated to the lack of an annuloplasty ring. However, although some patients had no ring, they had some sort of reduction annuloplasty. If the annulus was already very small and only P2 was resected or if they had acute chordal rupture caused by fibroelastic deficiency, no annuloplasty ring was used. Patients with fibroelastic deficiency frequently have a normal mitral annulus. I would like to hear Professor Carpentier's opinion on this.

We found no predictors of recurrent MR in this series. We always use a ring in patients with myxomatous disease of the mitral valve because the annulus is always dilated in these patients. Maybe Professor Carpentier can make a comment about the need for a ring in patients with fibroelastic deficiency.

Dr Carpentier. I enjoyed very much that you differentiated between fibroelastic deficiency and Barlow syndrome despite your pathologist. They are 2 different diseases. You are absolutely right.

Now, it is true that in fibroelastic deficiency you have a type II P2 caused by one single ruptured chord, and the rest of the valve seems to be normal. The problem is that the fibroelastic deficiency involves not only the leaflet and the chordae but also the whole valvular apparatus. Placing a ring takes an additional 15 minutes, and this is the price to pay to have a long-lasting repair and stabilization of the annulus for the rest of the life of the patient because our aim today is no longer to correct the mitral valve deficiency but to provide a lifelong cure.